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A Comparative Analysis of Deep- Cycle and Regular Batteries for Resistive Loads

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ABSTRACT: batteries also known as starting lighting ignition batteries have found applications in most common engines with little consideration for their application in deep cycle power system. This is due to the presence of deep cycle discharge batteries which have been designed to provide moderate flow of electrical current with higher depth of discharge and possibly long service life. This work is a comparative analysis of regular and deep cycle batteries using 40Ah of both batteries as a case study in order to ascertain their viability, benefits and drawbacks. The work involves the conduct of literature review on battery technologies including their charge and discharge characteristics as they relate to regular and deep cycle system application; carrying out a comparative analysis of the characteristics of regular and deep cycle batteries, as well as carrying out experimentation and analyzing the performance of regular and deep cycle (Flooded) batteries. Findings from the experiments revealed that the open circuit voltage for deep cycle battery (13.2V) was higher than that of a regular battery (12.79V). Also, a load test experiment carried out on both battery types revealed that the power output on the average when the regular battery as source was higher at low load of 3.6Ω than deep cycle battery with same load value. The output power at 3.6Ω was 59.114W for regular battery and 54.819W for deep cycle battery while at higher resistance (10.4Ω, 17.3Ω and 22.1Ω) the output power was lower (16.092W, 9.764W and 7.543W) for regular battery and (17.042W, 10.399W and 8.287W) for deep cycle battery. Also, the discharge rate of the deep cycle battery was 20hr while that of regular battery was 15.1hr on the average. However, it can be concluded from the experiments that the regular battery can also be applied in deep cycle power system even though its duration is low and discharge rate is high when compared with deep cycle battery

KEYWORDS: Battery, Regular, Deep cycle, Discharge, Technology, System

1. INTRODUCTION

Energy storage systems remain essential for modern power systems in both conventional and renewable applications [1]. The developing countries in the world are most affected at low availability of conventional power. Example is Nigeria that witnessed drastic dropped in conventional power generation 8,000MW with only 4,000MW operational of which only about 1,500MW is available [2]. Solar system option is also faced with similar problems. Nigeria has average solar radiation intensity of 5kWh/m^2/day and for proper installation of PV panels, an average of 192000MW of solar energy could be produced on daily basis. In addition, the solar radiation in the coastal region of Nigeria fluctuates around 3.5kWh/m^2/day for an average sunshine of about nine hours per day in the dry season and five hours per day in the rainy season [3]. Improper installation of solar panels in compliance to tilt-angle orientations, affect key sector of every Nation economy using solar energy. This include the rapid growth in Information and Communication Technologies (ICTs) that has strong impact on human activities globally including service delivery models of many organizations with respect to healthcare, businesses, education and governance [4]. A case is the role of power supply to e-library equipment most especially as it affects internet connectivity for effective library utilization E-libraries [5]. Following the invention of distributed renewable energy generation and electric automobile as seen with electric vehicles (EV), the utilization of battery as a form of energy storage has become more prevalent [6].The amount of energy storage in batteries power required due to charging and discharging rates [7]. Further application of energy storage gadgets can be found in ensuring a balanced variable power source characterized by renewable energy form such as deep cycle, wind and hydro, provide ancillary services such as voltage and frequency stability, and backup power supply system [8]. Furthermore, the lead-acid battery is among the earliest and fully developed forms of battery for energy storage and it was invented in the 18th century [9]. Hence, it is seen as the oldest type of battery being used today in our modern world and it is characterized by low cost. Lead-acid batteries are popular for energy storage, and the type to be employed depends on the application. The deep cycle lead acid battery is commonly used for photovoltaic solar system, while the starting lighting ignition (SLI) lead acid battery is utilized in automobile systems [11]. By design, regular batteries are built to sustain high amount of current which could be as high as 200Amps in few seconds in addition to complimenting the alternator in supplying power DC electrical loads in the vehicle [12].

2. LITERATURE REVIEW

A battery is a device that stores chemical energy. This stored chemical energy can be converted to electrical energy and consumed. The process of energy conversion from chemical to electrical involves the drift of electrons. This process is considered as electrochemistry, and the system that supports a battery function is known as electrochemical cells which consist of two electrodes (anode and cathode) and a separator that separates them. The chemical reaction which occurs involves drift of electrons from the anode to the cathode through a separator [13]. As chemical reaction takes place at the anode and produces electrons, there is a need to maintain neutral charge balance on the electrode and as such, a matching amount of positively charged ions is also produced [14].

2.1 Battery Parameters

Batteries are generally evaluated based on some parameters which are considered as battery parameters [15]:

a. **Battery capacity**
The storage capacity of the battery is basically represented in Ampere hour (Ah). By consideration to the voltage, the battery storage capacity in terms of energy is taken as Ampere-Hour-Volt which is equal to Watt-hour. The battery’s capacity is specified, giving the discharge/charge rating, while the actual battery capacity depends on operating conditions such as temperature and load.

b. **Battery voltages**
A battery has a terminal voltage that is seen as the nominal or working voltage, and this is specified by the manufacturer. Some of the voltages include; 6V, 12V, 24V, etc

c. **Depth of discharge (DOD)**
This Depth of discharge (DOD) gives the level of energy which is taken from a battery as a percentage of its full capacity. The disparity amid the full charge and the depth of discharge of a battery is considered the state of charge which is represented in percentage. If the DOD is 25% then the state of charge is 75%.

d. **Discharge/charge rate or C-rate**
The charge rating of a battery is the value obtained by giving the ratio of the capacity of the battery to the count of hours for it to be fully charged or discharged. The charge or discharge current for a C-rating can be calculated by dividing the Ah capacity of a battery by the total hours of charge and discharge. For example, in a 50Ah capacity battery, if the C rating is 0.1 C then the charge or discharge current will be 50/10 = 5A.

e. **Self-discharge**
This is considered the electrical capacity lost when a battery is not being utilized based on its internal electrochemical process. The self-discharge increases with an increase in temperature. Hee, a battery may be stored at lower temperatures in order to reduce self-discharge.

2.2 Types of Battery

The following are different types of batteries: Lead acid**,** Nickel Cadmium (Ni-Cd), Nickel–metal hydride (Ni MH) and Lithium-ion. The energy density of Li-ion batteries is three times more than lead acid batteries. A few cells in series will give the required battery voltage. The lithium electrode’s reaction with the regular creates a passivation film during every discharge and charge operation. This is compensated by the usage of thick electrodes. Because of this fact, the cost of Li-ion battery is higher than that of NiCd batteries. Further overcharging damages the battery **[16, 17].**

Batteries found applications in domestic, commercial, and industrial settings. These applications include usage in deep cycle power systems, electronic systems, and starting automobile engines. Cellular phones batteries are recycled in operations.

A comparison of some parameters of both batteries is depicted in Table 1 [18].

Table 1: Comparison between SLI and Deep Cycle lead Acid Batteries

S/N	PARAMETERS	STARTING LIGHTING IGNITION (SLI)	DEEP CYCLE BATTERY
1	**Types of Battery**	Lead acid	Lead acid
2	**Optimal discharge before recharging**	45% - 75%	Up to 5%
3	**Plate Material**	Lead plates	Lead plates, Lead dioxide plates
4	**Density of plates**	Thicker	Thinner
5	**Produced current**	Steady lower current	Higher current
6	**Application**	Regular	Deep cycle PV system
7	**Mixture of Sulphuric acid with Water**	35% Sulphuric, 65% Water	35% Sulphuric, 65% Water

The presentations above have not carefully study the behavioral tendencies of different batteries of the same capacities and ratings to resistive loads. This is what this study tends to address.

3. MATERIALS AND METHOD

The essence of this research is to compare the performance of deep cycle and regular batteries. An experiment to conduct an investigation on the performances of 40Ah deep cycle and regular (SLI) batteries under room conditions was carried out on a deep cycle battery and regular battery (SLI) of the same capacity. They were subjected to various tests, the results analyzed and presented as findings from this research. A schematic view of the experimental setup is shown Figure 1

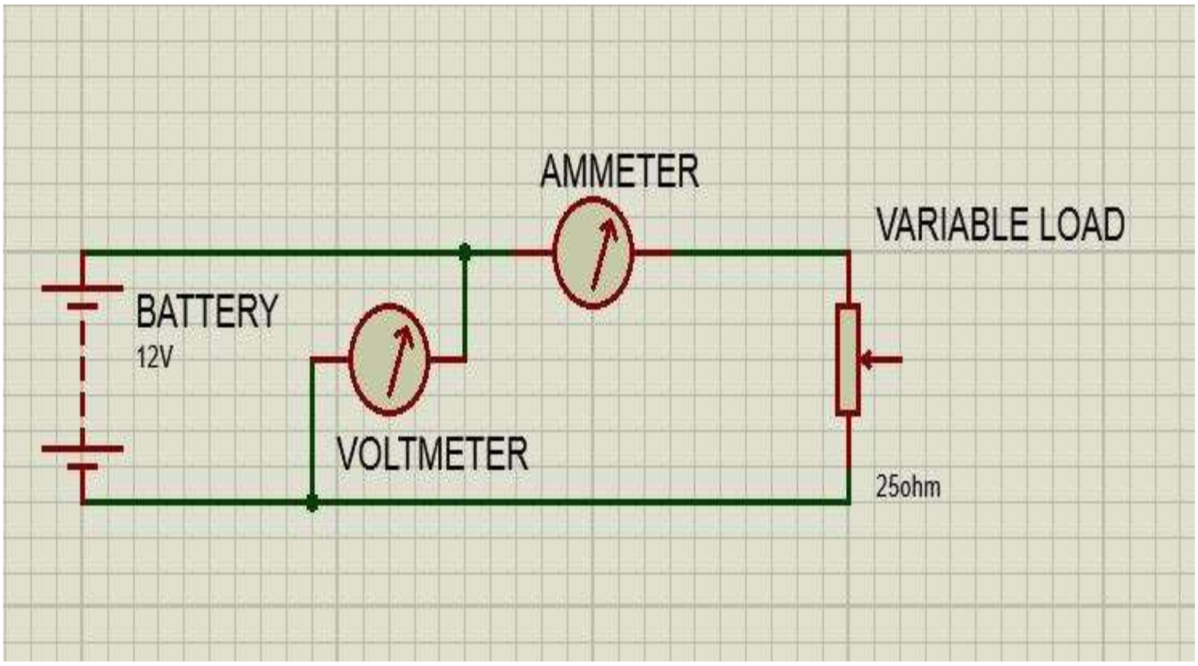

Figure 1: Experimental Setup Circuitry

As shown in Figure 1, a battery is connected to a load with a voltmeter and an ammeter also connected in parallel and in series respectively with the battery and load. The load is a variable type that functions within a range of resistance.

3.1 Specimens and Parameters

The following are specimens for the experiment. A 40Ah Deep Cycle Battery, 40Ah Regular (SLI) Battery and a (0-25)Ω variable resistor which served as load. The batteries specifications presented in tables 2 and 3 respectively.

Table 2: Specification of 40Ah Deep Cycle Battery

Battery Model	GEL-40-12
Battery Type	Lead acid
Rated Capacity (Ah)	40
Nominal Voltage (V)	12
Full charge (V)	12.8 – 13.4
Cut off Voltage (V)	10.5
Internal resistance	0.3Ω
Operation temperature range (°C)	-40 to 65
Initial charging current (A)	Less than 20A

Table 3: Specification of 40Ah Regular (SLI) Battery

Battery Model	Solite
Battery Type	Lead acid
Rated Capacity (Ah)	40
Nominal Voltage (V)	12
Full charge (V)	12.4 – 12.8
Cut off Voltage (V)	10.5
Internal resistance	0.2Ω
Operation temperature range (ºC)	-20 to 40
Initial charging current (A)	Less than 20A

Furthermore, a digital multimeter was connected to the load for this test. As the knob of the load was adjusted, the output value of the load varied from 0 to 25Ω corresponding to the movement from 0-100% as presented in table 4.

Table 4: Resistance Value of Variable Load

PERCENTAGE TRAVEL (%)	LOAD RESISTANCE (Ω)
10	3.6
20	6.1
30	8.2
40	10.4
50	12.7
60	14.7
70	17.3
80	19.4
90	22.1

3.2 Experimental Tests

Open circuit test was carried out on both batteries to ascertain their condition before putting them to use. Both batteries were charged full and afterwards were tested for reliability based on open voltage test by connecting the multimeter across the batteries and setting it at voltage reading. The output value for the deep cycle battery was 13.2V while that of the regular (SLI) battery was a 12.79V. The batteries were also subjected to load test by connecting them to the load at different times when they are of full charge. The voltmeter was connected in parallel while the ammeter was connected in series. The load was varied from 10% to 90% to give 3.6Ω to 22.1Ω respectively. For every increment in load (resistance) value, the voltage of the battery and current output were read and documented. These values were processed and presented as findings for the research. The procedure was carried out using both the deep cycle and regular (SLI) battery at different times up to five cycles. Furthermore, Charge and Discharge Tests were also performed. This procedure involved testing the rate at which the batteries charge and discharge. At first, the batteries were charged full using an external battery charger and connected to a load value of 3.6Ω so as to allow for more current to be consumed. With the connection, the battery was left to discharge until its terminal voltage dropped to 10.5V which is the cut off voltage and the time taken was recorded. Similarly, this procedure was carried but in reverse on both batteries as they were tested for their rate of charge. Employing a battery charger, each battery was subjected to charge at 15.5A after they have been discharged to cut off voltage. The batteries were charged till they became fully charged and the time taken to reach full charge was recorded.

4. RESULTS AND DISCUSSION

The results obtained for both Deep-Cycle and Regular (SLI batteries are presented for analysis..

4.1 Result of Load Test for Deep-Cycle battery

To carry out this test, the deep cycle battery was connected to a varying load device and the system turned on. The voltage readings of the battery and the corresponding current readings were obtained during the experimental process for five different reading cycles. Figure 4 is a linear curve the load as it varied from 0 to 100%. However, 100% load value was not achieved due to the design of the adjustable knob which serves as a stopper. Hence, the experiment was capped at 90% value for maximum load output.

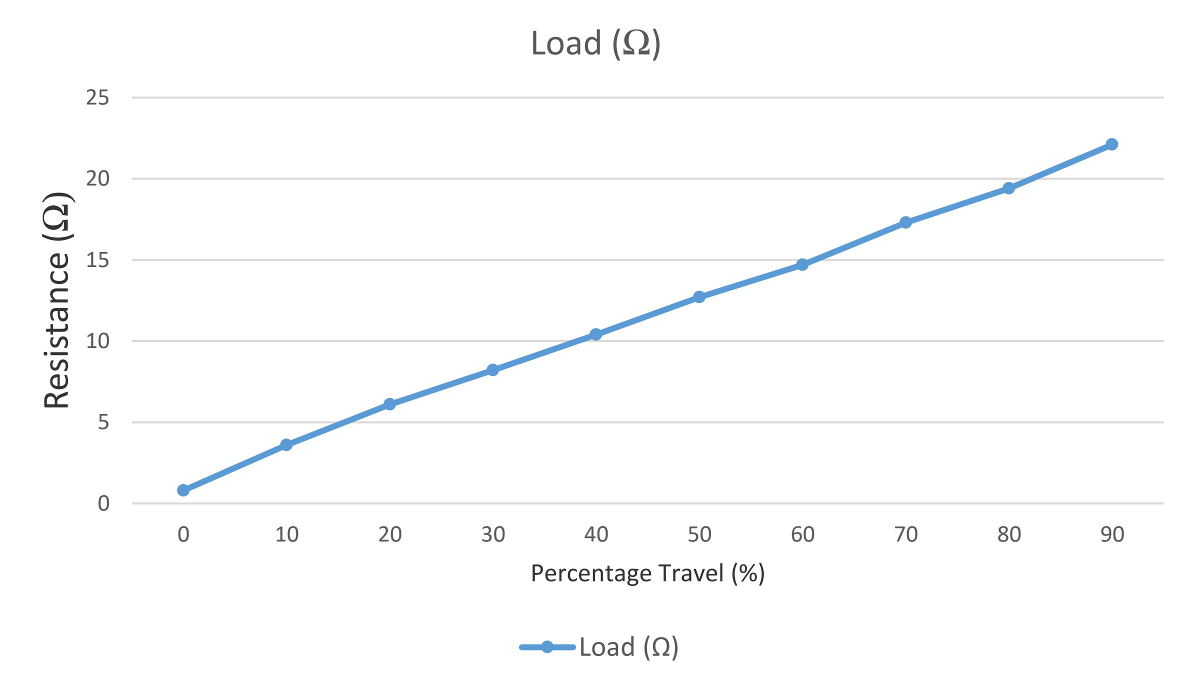

Figure 4: Plot of Resistance Value against Travel Percentage

As depicted in table 4, the highest voltage of the battery was obtained when the resistance of the load was at 90% travel (maximum travel for this study), resulting in a consequential low current output. Also, at the lowest resistance with 10% travel (minimum travel time for this study), the voltage value reduced further resulting in a consequential increase in the value of the current as depicted in Figure 5.

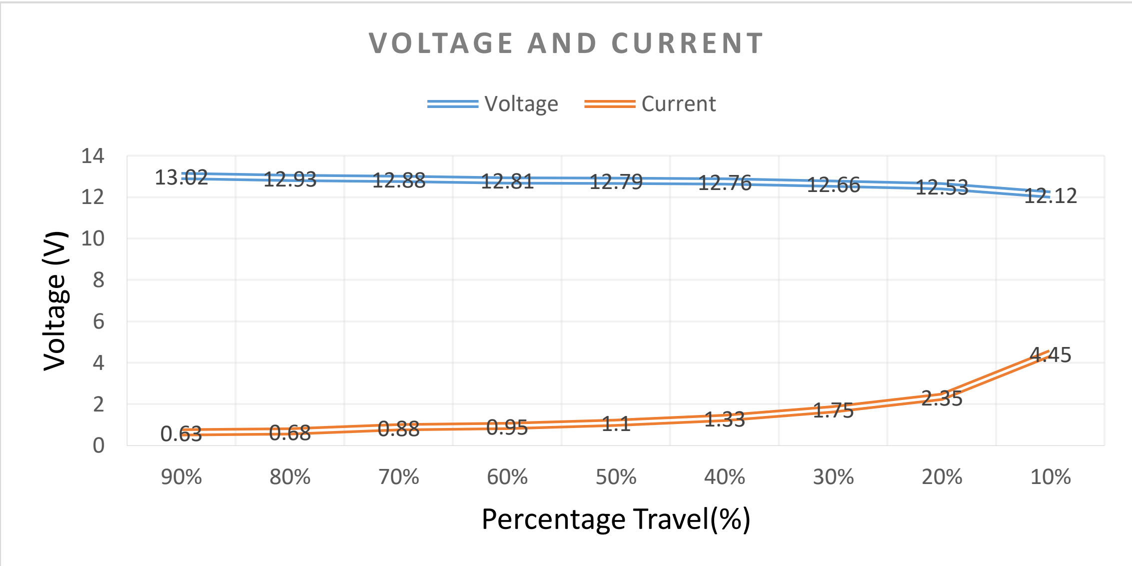

Figure 5: Voltage and Current Readings on Deep cycle Battery Load Test

According to ohm's law the voltage across a load is directly proportional the current as long as the resistance remains constant. Voltage drop occurs in a system when the load increases due to an increase in current which depletes the source capacity. As current flows across the internal resistance of the battery which is connected in series to the load, there is bound to be voltage drop. Increase in voltage drop was as a result of increase in current flow based on decrease in load (resistance).

Using equation 1

$$V_i = V_s + V_d \qquad (1)$$

Where,

$V_i = Ideal\ Voltages$

$V_s = Source\ Voltage$

$V_d = Voltage\ drop$

The measured voltage of the battery without load was 13.2V By computation, the voltage drop across the battery based on measured current can be given as follows: At 90% travel with load resistance of 22.1Ω and using internal resistance of 0.3Ω according to manufacturing specification,

$V_d = I \times R = 0.636 \times 0.3 = 0.191V$

$V_s = 13.2 - 0.191 = 13.009V$

$$Difference = Calculated\ Source\ Voltage - Measured\ Source\ Voltage \quad (2)$$

4.2 Result of Load Test for Regular Battery

To carry out this test, the regular (SLI) battery was connected to a varying load device and the system turned on. The voltage readings of the battery and the corresponding current readings were obtained during the experimental process for five different reading cycles. The highest voltage of the battery was obtained when the resistance of the load was at 90% travel (maximum travel for this study), resulting in a consequential low current output. Also, at the lowest resistance with 10% travel (minimum travel for this study), the voltage value reduced further resulting in a consequential increase in the value of the current as depicted in Figure 6.

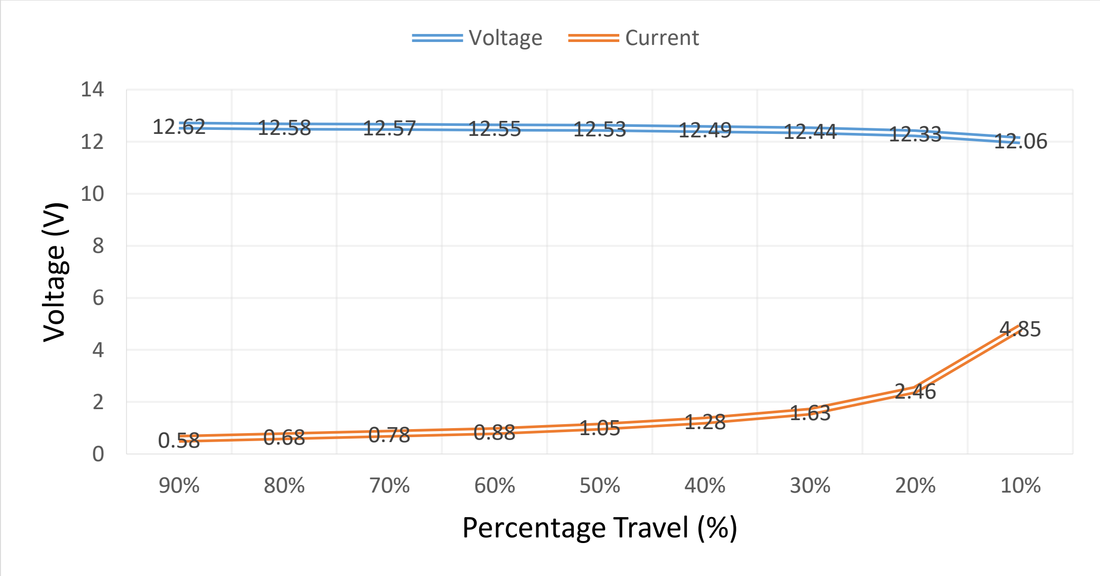

Figure 6: Voltage and Current Readings on Regular (SLI) Battery Load Test

The measured voltage of the battery without load was 12.79V By computation, the voltage drop across the battery based on measured current can be given as follows: At 90% travel with load resistance of 22.1Ω and using internal resistance of 0.2Ω according to manufacturing specification,

$V_d = I \times R = 0.598 \times 0.2 = 0.12V$

$V_s = 12.79 - 0.12 = 12.614V$

$$Difference = Calculated\ Source\ Voltage - Measured\ Source\ Voltage$$

4.3 Power Output Comparison between Deep cycle and Regular Battery

The power used up by the load at varying resistance, the voltage output was captured alongside the corresponding current value across the system.

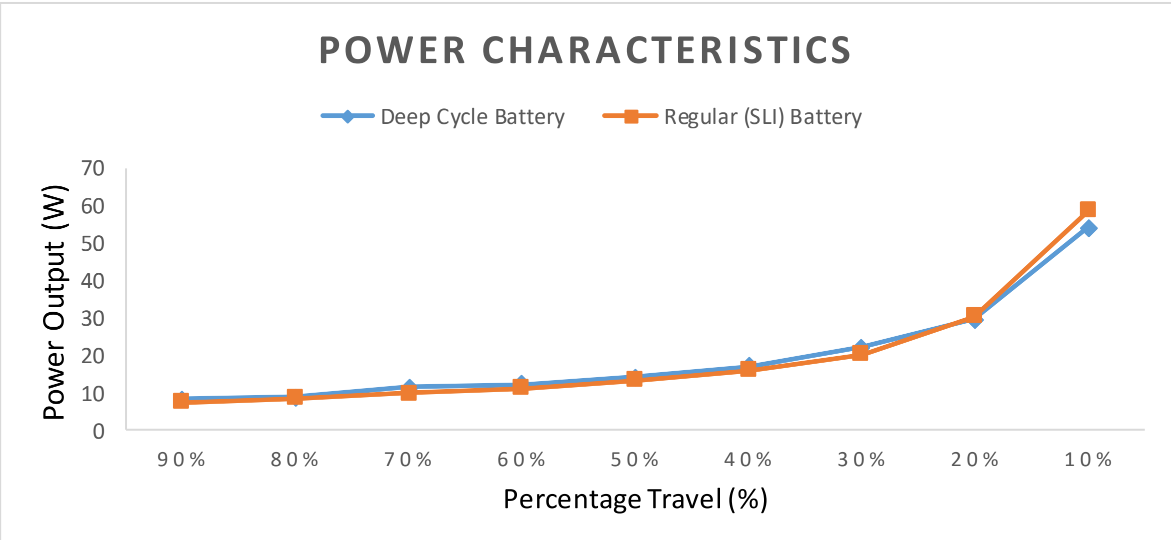

Figure 7: Performance of Deep cycle Battery against Regular Battery

As can be seen in Figure 7, when the percentage travel was at 10% which indicates low resistance of 3.6Ω, the regular battery produced a power output of 59.114W which was higher than that of the deep cycle battery (54.819W) at same load. This indicates the ability of regular batteries to provide higher start up current when employed for such applications compared to deep cycle battery. In a similar situation, the power output at 80% travel was 30.169 W for regular (SLI) battery as against 30.062W for deep cycle battery. This further indicates a higher current flow for the regular (SLI) battery compared to the deep cycle battery. However, as the load is increased, the power output for both batteries is reduced; but a further reduction was seen with regular (SLI) battery compared to deep cycle battery relying to the curve in figure 7. This indicates that the deep cycle battery was able to produce steady current flow at various source voltages to the load thereby producing a less sloppy curve compared to regular (SLI) battery. Thus, the performance of deep cycle battery when it comes to supplying steady current to load system appears more effective than regular battery. However, the regular (SLI) battery appears to have almost a similar performance in power characteristics and as such can be employed in deep cycle power system applications.

4.3. Result of Charge and Discharge Test

4.3.1. Discharging Test

Both the deep cycle and regular (SLI) battery were subjected to discharge test and the results presented in Figurea 8 and 9. After charging the batteries till they became fully charged, they were discharged by connecting them to a load of 3.6Ω for deep cycle battery and 3.8Ω regular(SLI) battery respectively to give a current of approximately 4.5A.

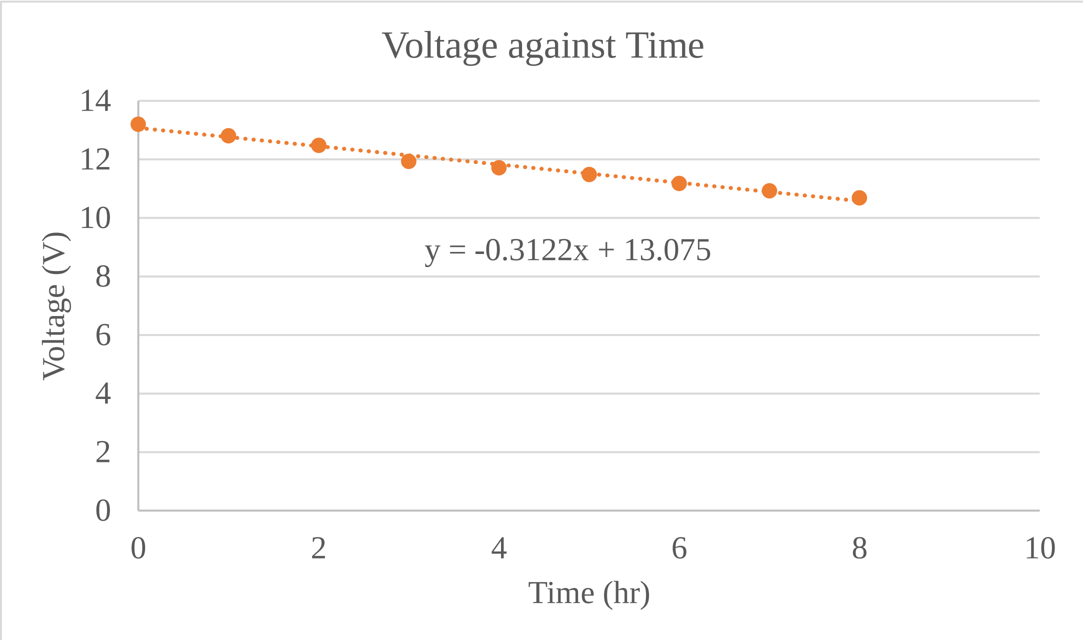

Figure 8: Plot of Voltage against Time during Discharge (Deep Cycle Battery)

Figure 8 shows the plot of the voltage against time during the discharge process. It is a linear graph and from it an equation was established. This equation governs the performance of the battery with respect to its discharge characteristics. By interpretation of the x and y axis, the equation becomes,

$$V = -0.3122t + 23.075$$

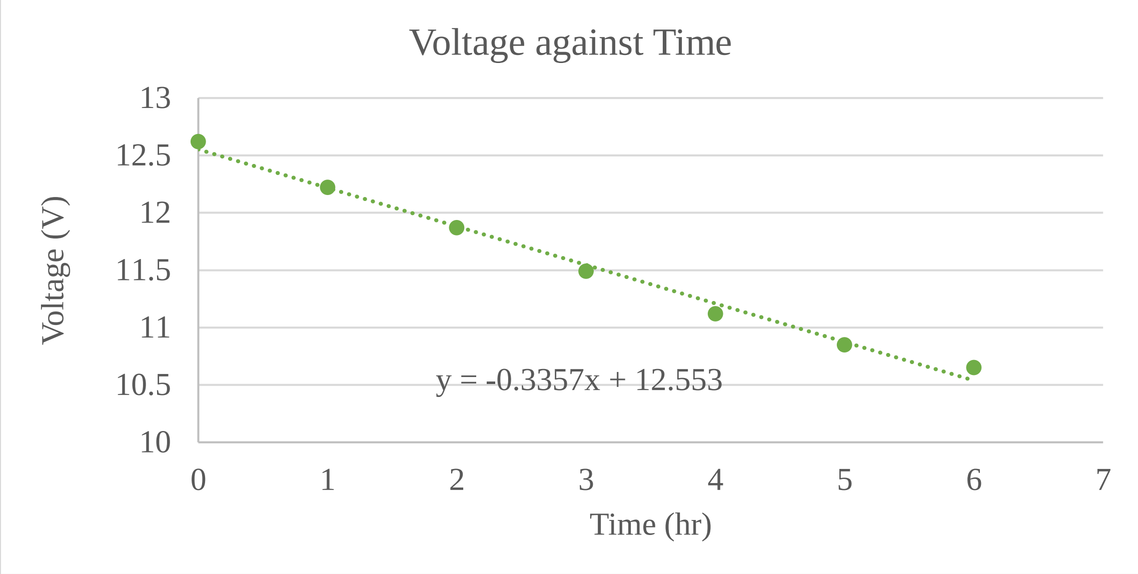

Figure 9: Plot of Voltage against Time during Discharge (Regular (SLI) Battery)

Figure 9 shows the plot of the voltage against time during the discharge process. It is a linear graph and from it an equation was established. This equation govern the performance of the battery with respect to its discharge characteristics. By interpretation of the x and y axis, the equation becomes,

$$V = -0.3357t + 12.553$$

After several hours, the batteries were discharged to a cut off voltage of 10.5V and time taken during the discharging process as recorded. This procedure was executed three times and the various time value recorded.

Table 10: Discharge Rate Test of Batteries

Discharge Rate	Test 1 Duration(h)	Test 2 Duration(h)	Test 3 Duration(h)	Average Duration(h)
Deep Cycle Battery	8.91	8.82	9.23	9.0
Regular(SLI) Battery	6.98	6.35	7.11	6.8

This procedure was carried out three times and the various time value recorded. The average time taken to discharge deep cycle battery was 9 hours which is higher than regular battery of 6.8 hours. Hence, when connected to same load, deep cycle battery performs better in providing power supply for longer duration of hours compared to regular battery. However, because the regular battery was able to supply power over a period of time, it indicates it can be used for deep cycle power system application but with consideration to duration capacity.

4.3.2. Charging Test

After discharging the batteries till they reached 10.5V, the deep cycle and regular batteries (SLI) were subjected to charging till they attained their full voltage of 13.2V for deep cycle and 12.8V for regular (SLI) batteries. The batteries were connected to an automatic charging source which self regulates the quantity of charge that goes into a battery being charged until it becomes fully charge. The voltage of the batteries were recorded every hour until the batteries were fully charged as depicted in Figure 10 and 11.

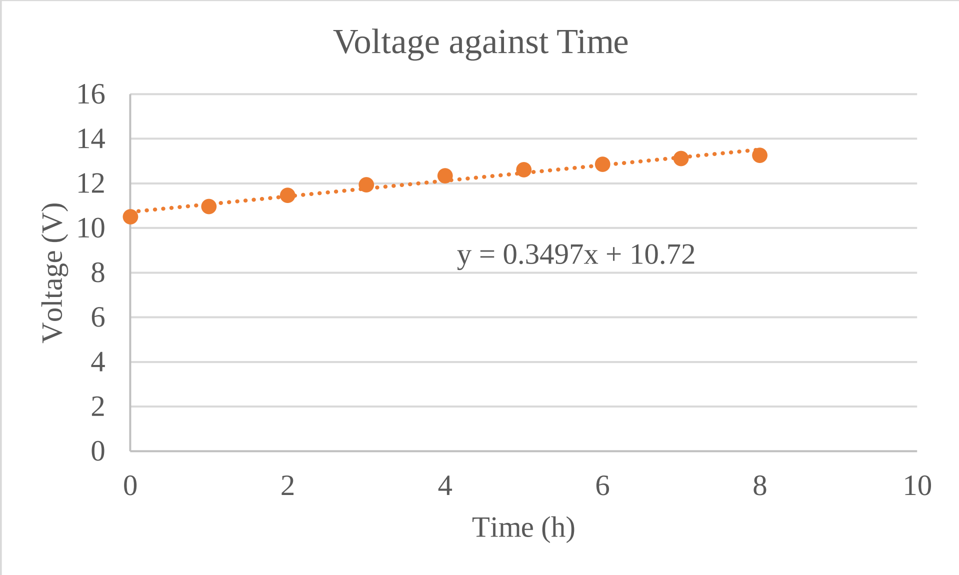

Figure 10: Plot of Voltage against Time during Charge (Deep Cycle Battery)

Figure 10 shows the plot of the voltage against time during the course of discharge. It is a linear graph and from it an equation was established. This equation governs the performance of the battery with respect to its discharge characteristics. By the interpretation of the x and y axis, the equation becomes,

$$V = 0.3497t + 10.72$$

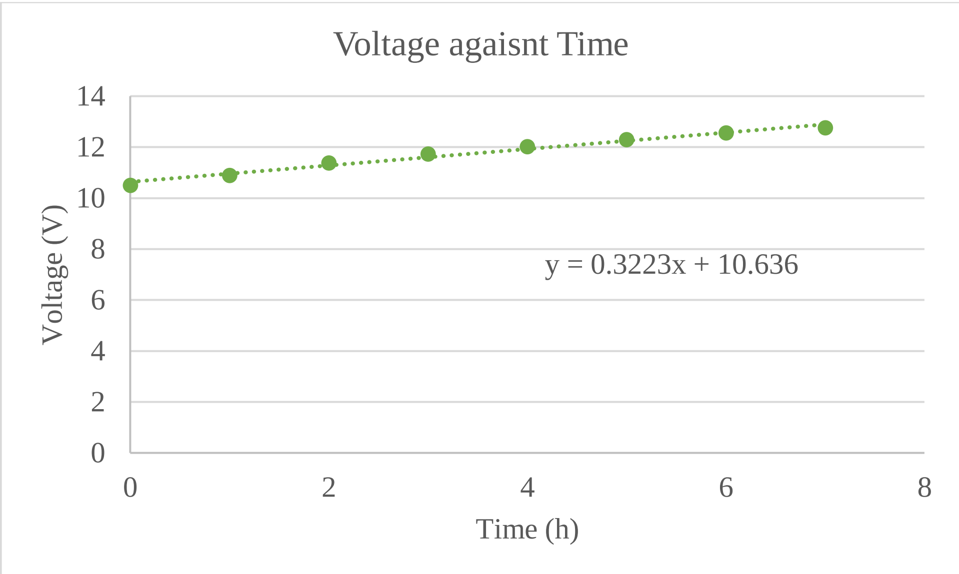

Figure 11: Plot of Voltage against Time during Charge (Regular (SLI) Battery)

Figure 11 shows the plot of the voltage against time during the course of discharge for which it appears to be a linear graph and from it an equation was established. This equation governs the performance of the battery with respect to its discharge characteristics. By interpretation of the x and y axis, the equation becomes,

$$V = 0.3223t + 10.636$$

Table 13: Recharge Rate Test of Batteries

Charge Rate	Test 1 Duration(h)	Test 2 Duration(h)	Test 3 Duration(h)	Average Duration(h)
Deep Cycle Battery	8.2	7.9	8.2	8.1
Regular(SLI) Battery	6.9	7.0	6.8	6.9

This procedure was carried out three times and the various time recorded. As seen in table 13, the time it took for the discharged deep cycle battery to become fully charged was 8.1 hours while that of the regular battery was 6.9 hours on the average. This implies that the deep cycle battery takes longer time to be fully charged compared to regular (SLI) battery. However, comparing the rate of discharge to the rate of charge, the deep cycle battery performs better but it is also an indication that the regular battery can be applied in deep cycle power system.

CONCLUSION

The crux of this research is to carry out a comparative analysis on the characteristics of regular (SLI) and deep cycle batteries through robust experimentation and analysis of their performances under various cases. The findings from the experiments revealed that the open circuit voltage for deep cycle battery is higher than that of a regular battery. The load test experiments carried out on both battery types revealed that the power output when using the regular (SLI) battery as source was higher at low load (resistance) than deep cycle battery but became lower as the load increases. Deep cycle battery displayed moderate current flow, lasted longer and had a lower discharge rate compared to regular (SLI) battery. However, it could be concluded from the research that the regular (SLI) battery can also be applied in deep cycle power system even though it has a faster discharge rate; thus, does not last as much as its deep cycle counterpart. Also, the faster rate of charge of regular (SLI) revealed by the research makes it suitable to be employed in deep cycle power operation as well.

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